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Impacts of Gold Extraction In the EU

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Industrial Ecology - Nutritional Health

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1. CONTEXT

1.1. BACKGROUND OF GOLD EXTRACTION

1.1.1. CYANIDATION AND GOLD EXTRACTION METHODS

Leaching with sodium cyanide (cyanidation) is currently the most widely used method for gold processing operations because of its availability, effectiveness, and economics. More than half of all gold and silver mines in the world rely on the use of cyanide.

First used on a large scale in the 1970s, cyanide heap leaching allows miners to extract microscopic gold flecks from low-grade ore. In a typical heap leach operation, vast quantities of rock are crushed and piled onto clay and plastic liners in huge decks. A sodium cyanide solution is sprayed onto the mound, passes through the rock layers, and in doing so extracts the gold out of the ore. Up to 97% of the gold is thus extracted, enabling the most microscopic bits of gold to be extracted from low grade ore¹. The technique of open leaching is not used in Europe however, and should not be recommended, because of the potential impacts on human health and the environment (see section 1.2).

At least three main types of gold extraction methods exist and are used worldwide²:

- Pretreatment of refractory gold ore:
 - Bacterial oxidation
 - Pressure oxidation
 - Roasting
 - Emerging technologies: thiosulphate leaching, resin-in-pulp, Augment, the Albion process, Activox and others.
- Leaching:
 - Conventional cyanidation, 1) Using agitated pachuca tanks³ or high-efficiency mechanically-agitated vessels, 2) Through heap leaching: simple and relatively cheap
 - Thiosulphate leaching for leaching of carbonaceous ores
- Carbon-extraction processing:
 - Carbon-in-leach (CIL)
 - Carbon-in-pulp (CIP)
 - Carbon-in-column (CIC)

¹ Information provided by Rainforestinfo.org, Accessible at : www.rainforestinfo.org.au/gold/cyanide.html, retrieved March 9, 2010

² Classification provided by Bateman engineering BV, Netherlands, Accessible at : www.batemanengineering.com/TECHNOLOGY/TechnologyTechnicalPapers/GoldBrochure.pdf, retrieved March 11, 2010

³ A high and narrow tank, with a central cylinder for the introduction of compressed air, used in the agitation and settling of pulp (pulverized ore and water) during treatment by the cyanide process.

1.1.2. TERMINOLOGY

- **Cyanide** is hydrocyanic acid, or any of its salts or derivatives
- **Leaching** is a widely used extractive metallurgy technique which converts metals into soluble salts in aqueous media.
- **Cyanide leaching** is the process of dissolving metals or metal compounds in a cyanide solution
- **Extractive industries** means all establishments and undertakings engaged in surface or underground extraction of mineral resources for commercial purposes, including extraction by drilling boreholes, or treatment of the extracted material;
- **Treatment** means the mechanical, physical, biological, thermal or chemical process or combination of processes carried out on mineral resources, including from the working of quarries, with a view to extracting the mineral, including size change, classification, separation and leaching, and the re-processing of previously discarded waste, but excluding smelting, thermal manufacturing processes (other than the burning of limestone) and metallurgical processes;
- **Tailings** means the waste solids or slurries that remain after the treatment of minerals by separation processes (e.g. crushing, grinding, size-sorting, flotation and other physico-chemical techniques) to remove the valuable minerals from the less valuable rock

1.2. IMPACTS OF CYANIDE ON HUMAN HEALTH AND THE ENVIRONMENT

“Cyanide”, in general, refers to various compounds having the chemical group CN, that is, one single atom of carbon (C) and one single atom of nitrogen (N). Several plants, some soil bacteria, and several species of invertebrate organisms produce natural cyanide and related compounds. Nevertheless, cyanide compounds are seldom present in uncontaminated waters in measurable concentrations. The cyanide used at mining sites is the inorganic form of cyanide, ie. sodium cyanide, NaCN, a white solid that dissolves readily in water. Cyanide readily combines with most major and trace metals – a property that makes it useful in extracting metals from ores. It also tends to react readily with many other chemical elements, producing a wide variety of toxic, cyanide-related compounds. However, cyanide compounds degrade rapidly when diluted and do not persist in the environment.

1.2.1. TOXICITY AND HEALTH IMPACTS OF CYANIDE COMPOUNDS

When sodium cyanide dissolves in water, some of the cyanide ion converts into hydrogen cyanide (HCN) or hydrocyanic acid. The cyanide ion (CN⁻) and hydrogen cyanide (HCN) are often referred to as free cyanide. Both forms are highly toxic to humans and aquatic life if ingested. At a pH below 7.0, essentially all dissolved cyanide is present as HCN. Most mining process solutions, such as tailings solutions or leach solutions, are kept at alkaline pH levels

because metal extraction is more efficient at these levels. This prevents the formation of poisonous HCN gas⁴.

Cyanide is a fast acting poison because it binds to key iron-containing enzymes required for cells to use oxygen and as a result tissues are unable to take up oxygen from the blood⁴. Hydrogen cyanide is acutely toxic to humans and, in its gaseous state, can be fatal at exposure levels of 100 to 300 parts per million (ppm)⁵. A rice-grain sized dose of cyanide – ranging from 50 to 200 milligrams – can be fatal to humans⁶.

Exposure to high levels of cyanide for a short time harms the brain and heart, and can even cause coma and death. Workers who inhale low levels of hydrogen cyanide over a period of years have breathing difficulties, chest pain, vomiting, blood changes, headaches, and enlargement of the thyroid gland. Some of the first indications of cyanide poisoning are rapid, deep breathing and shortness of breath, followed by convulsions (seizures) and loss of consciousness.⁷

1. 2. 2. ENVIRONMENTAL IMPACTS OF CYANIDE

Cyanide enters air, water and soil from both natural processes and industrial activities. Most cyanide in surface water will form hydrogen cyanide and evaporate. In soil, at high concentrations, cyanide becomes toxic to soil microorganisms, and passes through soil into underground water. Cyanide concentrations of 1 microgram (one-millionth of a gram) per liter of water can be fatal to fish⁶.

Free cyanide volatilises at temperatures slightly above ambient temperatures, because its boiling point is 25.6°C. However, the presence of metals stabilises cyanide in the metallic complex forms and thereby causes its retention in the environments. As levels of metals increase, the cyanide levels also increase⁸.

The most significant risk from the use of cyanide solutions in gold mining is the possible leaching into soil and groundwater. Mining operations now take additional precautions to prevent cyanide solution from escaping into the environment, by containing the layers of ore and ground up rock in special leach pads lined with a plastic membrane to prevent leaching. The cyanide is finally captured and recycled. In order to minimise the impact of unrecycled cyanide, mining facilities treat the cyanide waste through several processes, such as natural degrading in sunlight (photodegradation), or through hydrolysis and oxidation. The natural degradation can also be enhanced⁵.

⁴ Ballantyne, B., Blood, Brain And Cerebrospinal Fluid Cyanide Concentrations In Experimental Acute Cyanide Poisoning. *Journal of the Forensic Science Society*, **15**, 51-56., 1975.

⁵ Environmental literacy Council, Article on Gold mining, Accessible at : www.enviroliteracy.org/article.php/1120.html, retrieved March 11, 2010

⁶ Stanton M. D.; T. A. Colbert; and R. B. Trenholme, Environmental Handbook for Cyanide Leaching Projects: U.S. National Park Service, 57 pg. 1986.

⁷ Agency for Toxic Substances and Disease Registry (ATSDR).Toxicological Profile for Cyanide (Update). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. 2006.

⁸ Boadi, N.O., Twumasi, S.K. and Ephraim, J.H, Impact of Cyanide Utilization in Mining on the Environment, *Int. J. Environ. Res.*, 3(1):101-108, Winter 2009, Accessible at : www.sid.ir/En/VEWSSID/J_pdf/108220090111.pdf, retrieved March 11, 2010

NGOs maintain that both large- and small-scale gold mining damages landscapes, habitats, biodiversity, human health and water resources. Water especially is contaminated by cyanide, acid mine drainage, heavy metals and mercury from gold mining. The hydrologic cycle is changed and water sources are depleted by pumping water from aquifers.

1.3. EU CYANIDE DISASTERS AND SUBSEQUENT LEGISLATION

1.3.1. EU CYANIDE ACCIDENTS

Spills of cyanide solution and heavy-metal laced water can contaminate ground water, kill fish and waterfowl, and contaminate drinking water. Examples of recent disasters in the EU are provided in Table 1.

Table 1: Serious tailing dam accidents in the EU⁹

Mine	Date	Impact
Baia Borsa, Romania	10.03.2000	22,000 t of tailings contaminated by heavy metals released
Baia Mare, Romania	30.01.2000	100,000 m ³ cyanide contaminated water with some tailings released
Los Frailes, Spain	24.04.1998	4-5 million cubic meters of toxic tailings slurries released
Stava, Italy	19.07.1985	269 deaths, tailings flowed up to 8 km

After the gold extraction process, residues of cyanide can be stored in tailings dams for several years, in particular when there is no cyanide destruction step within the process plant. This was the case at Baia Mare in Romania in 2000, where a dam holding contaminated waters at a mining work burst, and nearly 100,000 cubic metres of cyanide and heavy-metal contaminated liquid spilled into the Lupus stream, reaching the Szamos, Tisza, and finally Danube rivers, killing hundreds of tonnes of fish and poisoning the drinking water in Hungary and Yugoslavia.

In Los Frailes, Spain, a tailings dam failure of the lead-zinc mine at Aznalcóllar near Seville released 4 to 5 million cubic meters of toxic tailings slurries and liquid into the nearby Rio Agrio, a tributary to Rio Guadiamar. The slurry wave covered several thousand hectares of farmland, and threatens the Doñana National Park, a UN World Heritage Area¹⁰.

⁹ Cyanide accidents mentioned on the Mineral Resources Forum. Accessible at: www.mineralresourcesforum.org/docs/pdfs/Bulletin121.PDF retrieved March 10, 2010

¹⁰ UNECE workshop on TDS, Yerevan, November 2007. Accessible at :

www.unece.org/env/teia/water/tailingdams/presentations/DanihelkaRISK_ANALYSIS_OF_TAILING_DAMS_F.ppt , retrieved March 10, 2010

1. 3. 2. EU MINING WASTE DIRECTIVE

The Mining Waste Directive¹¹ of 15 March 2006, on the management of waste from extractive industries, establishes harmonised best practices across the EU27, and directly addresses the circumstances that led to the Baia Mare accident. 25 Member States have transposed this Directive.¹²

Article 13.6 stipulates that “In the case of a pond involving the presence of cyanide, the operator shall ensure that the concentration of weak acid dissociable cyanide in the pond is reduced to the lowest possible level using best available techniques and, in any case, at waste facilities which have previously been granted a permit or have already been in operation on 1 May 2008 that the concentration of weak acid dissociable cyanide at the point of discharge of the tailings from the processing plant into the pond does not exceed 50 ppm as from 1 May 2008, 25 ppm as from 1 May 2013, 10 ppm as from 1 May 2018 and 10ppm at waste facilities which are granted a permit after 1 May 2008. If the competent authority so requests, the operator shall demonstrate, through a risk assessment that takes site-specific conditions into account, that those concentration limits need not be further lowered”¹¹.

According to the results of the UN assessment mission on the Cyanide Spill at Baia Mare, the tailings fluid in the pond, which covered some 93 hectares and was nearly 20m high in its final stage, contained a total concentration of cyanide of around 400mg/L, with about 120 mg/L of free cyanide¹³. This means that the concentration of cyanide required by the Mining Waste Directive, namely 10ppm, is twelve times less than the concentration in the pond.

The requirements stated in the Mining Waste Directive intend to prevent accidents such as those mentioned in section 1.3., and if applied may indeed prevent similar accidents from occurring. The Directive states that “in order to minimise the risk of accidents and to guarantee a high level of protection for the environment and human health, Member States should ensure that each operator of a Category A waste facility adopts and applies a major-accident prevention policy for waste. In terms of preventive measures, this should entail the delivery of a safety management system, emergency plans to be used in the event of accidents and the dissemination of safety information to persons likely to be affected by a major accident”. Annex 1 of the Directive details this major-accident prevention policy and information to be communicated to the public concerned.

The Directive states that the measures should be based on the concept of best available techniques, as defined in Directive 96/61/EC and, that “when such techniques are applied, it is for the Member States to determine how the technical characteristics of the waste facility, its

¹¹ The Mining Waste Directive, or Directive 2006/21/EC, was adopted by the European Parliament and the Council of the EU on March 15, 2006

¹² Only France and Estonia have not transposed it and/or notified their transposition to the Commission. The completeness and quality of transposition is now being assessed for the other Member States.

¹³ For further technical details on the Baia Mare Cyanide Spill of March 2000, please see the results of the Joint UNEP/OCHA Environment Unit UN assessment mission, accessible at : www.reliefweb.int/ocha_ol/programs/response/unep/rombaimare.html, retrieved March 31, 2010

geographical location and the local environmental conditions can, where appropriate, be taken into consideration”¹¹.

The European Commission Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities¹⁴ does not mention open leaching as a Best Available Technique. It specifies that during heap leaching, “the ore or agglomerated fine ore is stacked in heaps on a pad lined with an impermeable membrane. The gold bearing solution is collected on the impermeable membrane and channelled to storage facilities for further processing”. In a conventional milling and agitated leaching circuit, the ore is milled and conveyed as a slurry to a series of leach tanks, where the slurry is agitated to enhance the efficiency of the leach process. The process is described in detail in Chapter 2.3.4.2 of the BATs Reference Document. Both lined and unlined tailing ponds exist and various types of dams are used to confine the ponds. However, it is generally the sites using tank leaching that have carefully evaluated the acid rock drainage (ARD)-generation characteristics for their tailings.

1. 3. 3. EU LEGISLATION ON CYANIDE

The International Cyanide Management Code (ICMI)¹⁵ is a voluntary initiative, contrary to the Directive. It is considered that the recommendations of this code are de facto applied in the EU through various other EU regulations and directives, notably on the transport of dangerous matters and on the control of hazardous substances. These include, for example:

- For trade
 - Council Regulation (EEC) No 2658/87 on the tariff and statistical nomenclature and on the Common Customs Tariff
 - Directive 98/8/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market
- For transport
 - Council Directive 94/55/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road
 - Council Directive 96/49/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by rail
 - Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste
- For the control of substances
 - Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances

¹⁴ European Commission, Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities, January 2009. Accessible at : ftp://ftp.jrc.es/pub/eippcb/doc/mmr_adopted_0109.pdf, retrieved March 10, 2010

¹⁵ The “International Cyanide Management Code for the Manufacture, Transport and Use of Cyanide in the Production of Gold” (Cyanide Code) is a voluntary industry program for the gold mining industry to promote responsible management of cyanide used in gold mining, enhance the protection of human health, and reduce the potential for environmental impacts. Accessible at: www.cyanidecode.org/

- Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances
- Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register
- Regulation (EC) No 1272/2008 of the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures
- For environmental and human health
 - Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption
 - Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy

The European Standardisation Committee (CEN – Comité Européen de Normalisation) for methods of sampling and analysis is currently working on the elaboration and validation of an updated method for the determination of hydrocyanic acid, in execution of the mandate from the Commission to CEN. This mandate started in 2009 and should be finalised mid 2012.

1. 3. 4. EU CYANIDE BANS

A number of cyanide bans were implemented in different EU Member States, both prior to the implementation of the Mining Waste Directive, and in recent years (see Table 2).

Table 2: Cyanide bans in some EU Member States

Country	Year	Legislation
Hungary	2009	On 7 December 2009, the overwhelming majority of the Hungarian Parliament voted to oppose the use of cyanide in gold mining.
Germany	2002	A decree was passed prohibiting cyanide-leach mining.
Czech Republic	2002/2000	The Czech Senate of August 2002 and the Czech Parliament, of September 2000 made decisions to forbid gold production through cyanide leaching in the Czech Republic domain (Mining Law of 1991, article 30, paragraph

1.4. OBJECTIVES OF THE REPORT

Several companies have recently applied for the development of new gold extraction activities based on cyanide techniques within the EU, causing some emotion in the concerned Member States. Following this and the serious tailing dam accidents in Europe and cyanide bans in several EU countries, the question of a ban on the use of cyanide mining technologies has been raised.

The objectives of this report are to investigate

- the alternatives to the use of cyanide in gold extraction, and the additional costs of using these techniques
- whether the quantities of gold production, consumption and recycling in the EU are sufficient to justify such a ban on cyanide extraction
- what the possible consequences of such a possible ban at EU level might be.

2. ECONOMICS OF GOLD IN THE EU

2.1. GOLD PRODUCTION IN THE EU

2. 1. 1. EU GOLD MINING PRODUCTION COMPARED TO WORLD PRODUCTION

European gold mining production is small compared to the overall world production: the map of major gold mining activity in the world in 2006 (Figure 1) shows the world gold output as a percentage of the top producer (South Africa with 294 tonnes). None of the EU countries achieve as little as one percent of South Africa's annual production. Only 1% of world gold mining is mined in the EU¹⁷ (Figure 2).

Figure 1: Major gold mining activity in the world in 2006
Source: Minerals UK, British geological survey¹⁶

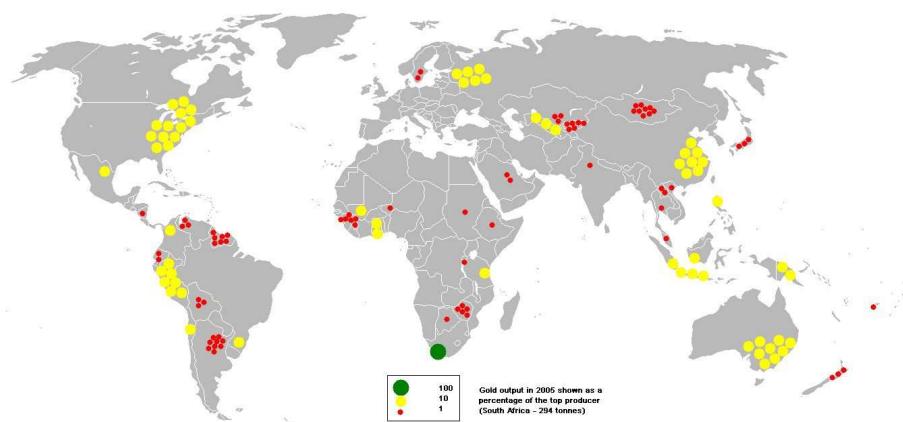
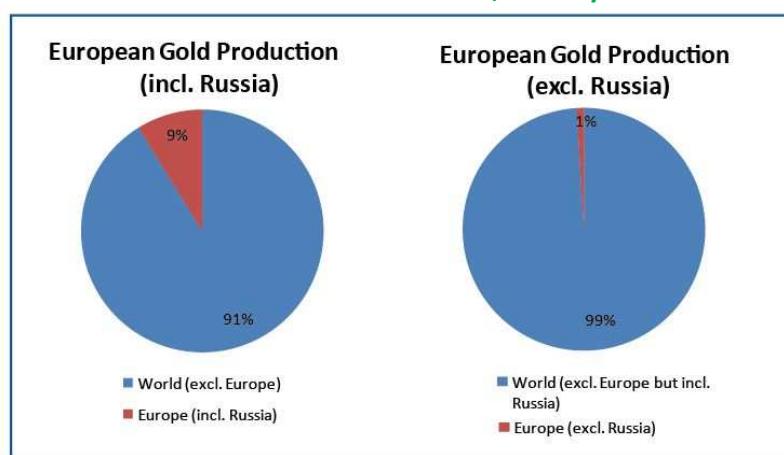


Figure 2: European Gold Production (incl. and excl. Russia)
Source: World Metal Statistics, January 2010¹⁷



¹⁶ British Geological Survey data. Accessible at: www.bgs.ac.uk/mineralsuk/commodity/world/home.html, retrieved March 11, 2010

¹⁷ World Metal Statistics January 2010, published by the World Bureau of Metal Statistics on January 20 2010 (Volume 63 Number 1) ISSN 0266-7355

2. 1. 2. MAIN EU GOLD PRODUCERS

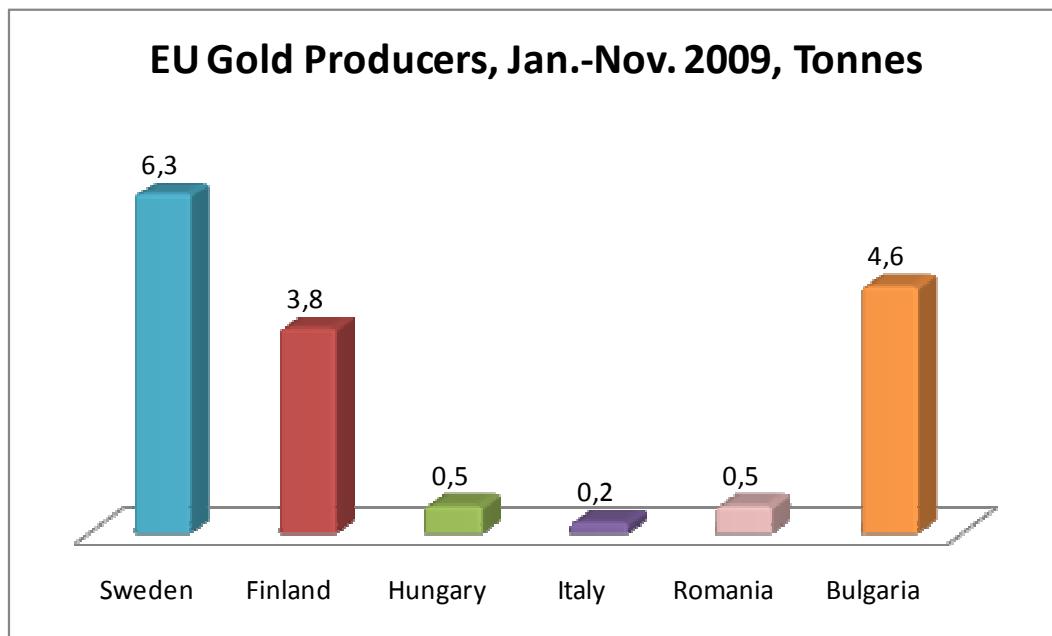
The six main gold producing EU Member States are Sweden, Finland, Hungary, Italy, Romania and Bulgaria (Figure 3). The World Metal Statistics report for January 2010 shows that these six countries account for 0.73% of the total world gold production¹⁷.

There has been increasing investment in gold exploration in recent years throughout the EU, with the exception of the Czech Republic and Hungary where gold mining has been banned. In the Czech Republic, there are gold reserves of at least 250 tonnes, of which the current market price is approximately 6 billion euros, but further prospecting has stopped because of the ban in place there – despite the fact that the Czech Republic is a large producer of cyanide for use in other sectors. Table 3, from the World Metal Statistics, illustrates the evolution of Gold Mine production in Europe.

Table 3: Europe Gold Mine Production¹⁷

	2005	2006	2007	2008	2008	2009	2009	2009	2009	2009
					Jan-Nov	Jan-Nov	Aug	Sept	Oct	Nov
EUROPE										
Armenia	1.4	0.9	0.6	0.6	0.6	0.6	0.1	0.1	0.1	0.1
Bulgaria	3.9	3.8	4.0	4.2	3.8	4.6	0.4	0.4	0.4	0.4
Finland	3.7	5.3	4.3	4.1	3.8	3.8	0.3	0.3	0.3	0.3
France	-	-	-	-	-	-	-	-	-	-
Georgia	1.6	2.4	3.1	3.1	2.8	2.9	0.3	0.3	0.3	0.3
Hungary	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0
Italy	0.6	0.6	0.6	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Portugal	-	-	-	-	-	-	-	-	-	-
Romania	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0
Russia	163.2	159.3	156.9	184.5	189.1	169.4	15.4	15.4	15.4	15.4
Serbia	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0
Spain	2.3	1.6	-	-	-	-	-	-	-	-
Sweden	6.6	6.8	5.2	4.9	4.5	6.3	0.7	0.8	0.8	0.8
Ukraine	0.5	0.5	0.5	0.5	0.4	0.5	0.0	0.0	0.0	0.0
Other Europe	1.0	1.4	0.7	0.7	0.7	0.7	0.1	0.1	0.1	0.1
Total	186.1	184.0	177.1	204.2	187.1	190.1	17.4	17.5	17.5	17.5

Figure 3: Main EU Gold Producers, 2009 (tonnes)¹⁷



2.2. GOLD CONSUMPTION IN THE EU

Gold is used for many different purposes, including electronics, space and aeronautics, medical uses, clean technologies, catalysts, dentistry, decorative uses, engineering, food and drink, and beauty. It is difficult however to establish the respective consumption of gold for each application, since gold is a material (i.e. a chemically defined substance) and not a product. Statistics are only available for products, and it is difficult to estimate the amount of gold that is used in the many different applications. In addition, production statistics may include double-counting, following the different uses of the gold.

About 80 percent of world gold production is used in jewellery, but approximately 600 tonnes are used each year for medical, dental, telecommunications, information technology and industrial purposes. Table 4 shows an overview of the figures for gold production, imports and exports in the EU, for the EU 27, in 2007.

**Table 4: Overview of gold production, imports and exports in the EU 27 (kg),
Jan.-Dec. 2007. Source: Eurostat Europrom database**

Indicators	Produced (P)	Imported (I)	Exported (E)	= P + I - E
Gold unwrought or in powder form for non-monetary use (including plated with platinum)	298 064	229 200	117 200	410 064
Gold in semi-manufactured forms for non-monetary use (including plated with platinum) (excluding unwrought or in powder form)	316 535	72 200	55 900	332 835

2.2.1. FINANCIAL SERVICES AND MONETARY EXCHANGE

The use of gold for monetary exchange was replaced by a system of convertible currency after World War II following the Bretton Woods system. The direct convertibility of currencies to gold has been abandoned by world governments.

For investment purposes however, gold is stored in the form of bullion coins or bars, as a hedge against inflation or various economic disruptions.

2.2.2. JEWELLERY

Pure, 24k gold is frequently alloyed with base metals in order to alter its hardness, melting point, colour and other properties. Jewellery remains the main use for gold throughout the world and the EU.

2.2.3. INDUSTRY AND ELECTRONICS

Gold is used in industry for a number of different purposes, such as gold solder, for jewellery, gold thread for embroidery, gold leaf for a wide variety of uses, gold toners in photography,

gold protective coatings for reflection purposes (e.g. in satellites as a reflector of electromagnetic radiation), or gold foil for heat dissipation (e.g. in car engines).

The catalytic potential of gold is being considered to tackle air pollution in aircraft and from cars, for use in the chemical industry, for fuel cells and in diesel-engine catalytic converters.

Gold is used in electronics since its properties make it highly conductive to electricity and generally resistant to oxidation and corrosion. For these reasons, it is used in electrical wiring, for coating electrical connectors, electrical contacts, or to connect semi conductor devices to their packages in wire bonding.

2. 2. 4. DENTISTRY

Gold is used for dentistry because of its malleability and resistance to corrosion. It is alloyed to reduce the softness. The trend is towards cheaper alloys with as little as 30% gold today however. Gold alloys have also suffered competition from new techniques such as ceramic dental crowns. In addition, social security payments for gold dental work have come under tighter scrutiny. These factors initially contributed to a sharp fall in gold use by the dental sector, but there has since been a recovery because of its non allergic properties – 60 tonnes annually worldwide¹⁸.

2. 2. 5. MEDICINE

Today, medical uses of gold have expanded greatly. It is used in surgery to patch damaged blood vessels, nerves, bones and membranes. It is also used in the treatment of several forms of cancer. Injection of microscopic gold pellets helps retard prostate cancer in men. Women with ovarian cancer are treated with colloidal gold, and gold vapour lasers help seek out and destroy cancerous cells without harming their healthy neighbours.

Gold has become an important biomedical tool for scientists studying why the body behaves as it does. By attaching a molecular marker to a microscopic piece of gold, scientists can follow its movement through the body. And because gold is readily visible under an electron microscope, scientists now, for the first time, can see whether and where a reaction takes place in an individual cell.

Some researchers are placing gold on DNA to study the hybrid genetic material in cells. Others are using it to determine how cells respond to toxins, heat and physical stress.

Because it is biologically benign, biochemists use gold to form compounds with proteins to create new lifesaving drugs. One experimental new gold compound blocks virus replication in infected cells. It is being tested for the treatment of AIDS.

Surgeons often use gold instruments to clear coronary arteries, and gold-coated lasers literally give new life to patients with once inoperable heart conditions and tumours.

¹⁸ World Gold Council, Uses of gold. Accessible at : www.goldipedia.gold.org/uses_of_gold/dentistry/, retrieved March 11,2010

The discovery of unexpected light emission properties of gold by a Texas A&M University chemist is leading to a wide range of applications in medicine, genetics and chemistry. The light emission properties of gold can also be used to detect diseases when gold attaches to nucleic acids in cells.

2.2.6. FOOD AND DRINK

Gold is used in food and drink with the E Number 175. Gourmet sweets and drinks use gold leaf, flake and dust as a decorative ingredient. Liqueurs such as Goldwasser contain flakes of gold leaf. However, the use of metallic gold has no nutritional effect since metallic gold is inert to all body chemistry.

2.3. GOLD TRADE IN THE EU

2.3.1. GOLD IMPORTS

In this section the term “metal” includes both unwrought and partly worked gold but excludes gold coin (British Geological Survey), whereas the term scrap refers to small pieces that have been left over after use for a specific purpose, e.g. from waste electrical and electronic equipment.

Imports of waste and scrap of gold have fluctuated since 1999, although exports have grown strongly since 2002. In 2006, the volume of EU-27 exports of gold and platinum scrap reached 7 647 tonnes¹⁹.

The clearly leading source countries for EU imports of ores and concentrates of precious metals in 2005 were South Africa, worth €343 million, and Indonesia, €187 million (Table 5). In South Africa the value of all platinum group metals (PGM) exports overtook gold in 2000, but, while gold production is declining, it remains the leading producer in the world. The “Environmental Impacts of Significant Natural Resource Trade Flows into the EU” report²⁰ estimates that Indonesia and Greenland are the second and third place countries for gold ore and concentrate exports to EU. It should be noted however that the ores from the Nalunaq Gold Mine in Greenland have been treated in Canada since 2007, thus influencing the current imports of gold to the EU mentioned in the following tables.

¹⁹ European Business, facts and figures, NACE Recycling and water supply, Eurostat

²⁰ AEA Energy & Environment, Environmental Impacts of Significant Natural Resource Trade Flows into the EU, Report to DG ENV, Issue Number 6, 2008

Table 5: Leading source countries for EU imports of ores (2005)

Source: Eurostat external trade database

	Value of Imports (Million Euro)	Volume of Imports (Thousand tonnes)
South Africa	343	0.8
Indonesia	187	0.01
Canada	35	0.09
Greenland ³⁶	21	117
United States	21	0.09
Argentina	11	0.2
Norway	5	0.01
Total of above	623	118.2
EU 25 (Extra)	637	120

The three main types of gold imported in the EU are non-monetary gold, closely followed (in value) by gold jewellery, and in third position, in far lesser quantities, gold ores (Table 6).

Table 6: Imports to EU of gold products (2005). Source: UN Comtrade Database

	Value of Imports to EU (Million €)	Volume of Imports to EU (Thousand tonnes)
Ores and concentrates of other precious metals (289.19)	631	n/a
Jewellery of gold, silver or platinum group metals (897.3)	3,712	n/a
Gold, non-monetary (excluding gold ores and concentrates) (971)	3,801	334

The UK is by far the biggest importer and exporter of gold metal in the EU (Figure 4). This most likely reflects the role spot or futures trading in the UK. The largest volume of gold trading occurs through spot and futures trading. The UK, Belgium-Luxemburg and Sweden were the largest importers of waste and scrap Gold in 2007.

Figure 4: Gold imports in the EU²¹

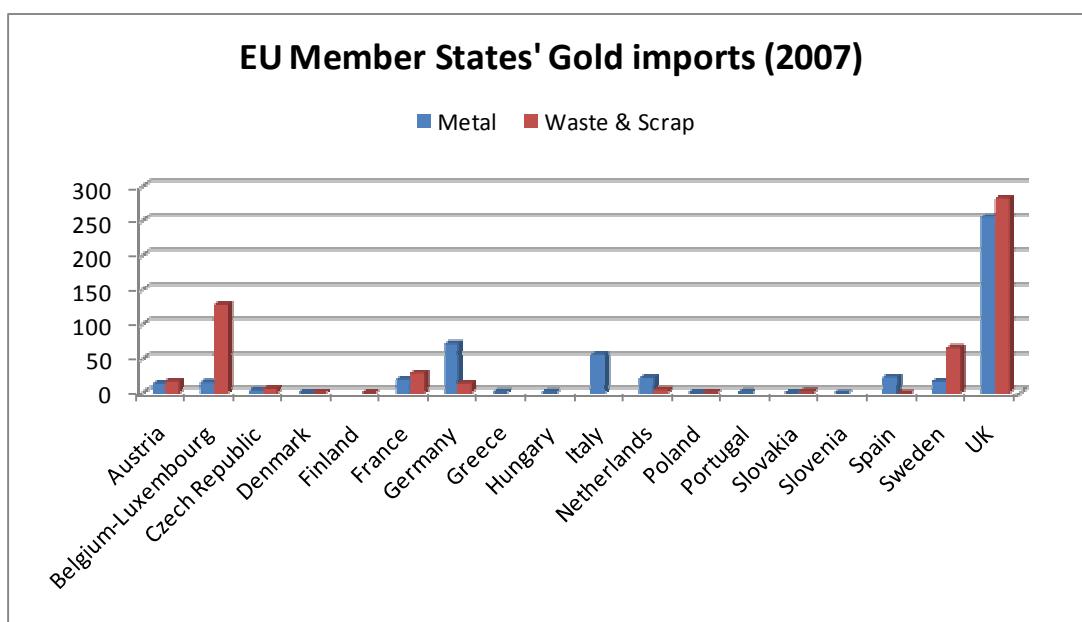
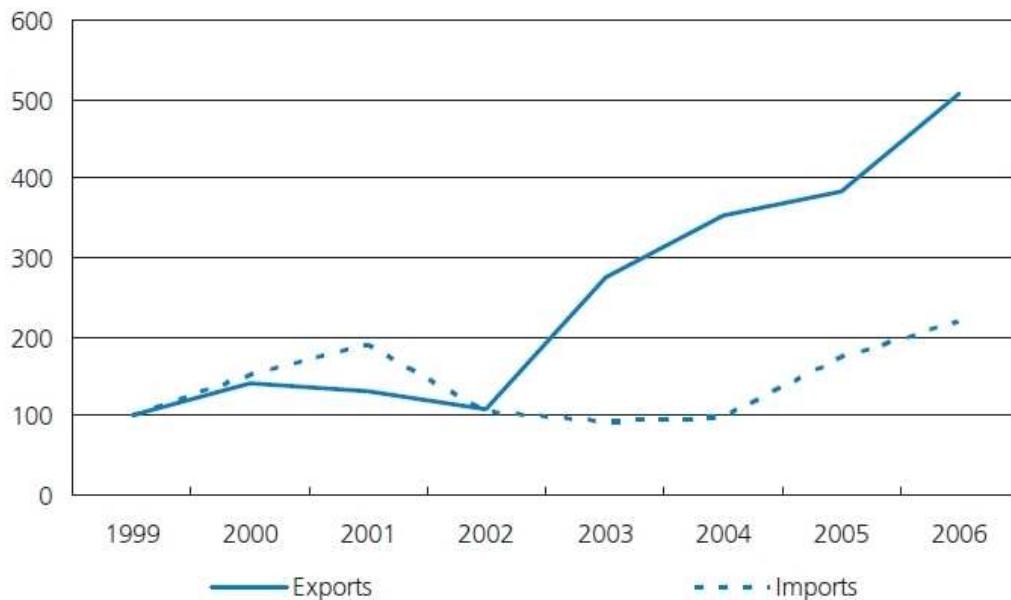


Figure 5 shows the development since 1999 in the quantity of imported and exported scrap of gold and platinum. Since 2002, the volume of waste and scrap gold and platinum exports has soared to more than twice the amounts of imports.

Figure 5: Quantity of external trade in waste and scrap of gold and platinum, 1999-2006 EU-27 (1999=100). Source: Eurostat (Comext)



The “Environmental Impacts of Significant Natural Resource Trade Flows into the EU” report²² demonstrates that for the commodity group “Ores and concentrates of precious metals;

²¹ British Geological Survey, European Mineral Statistics 2003-07. A product of the World Mineral Statistics database.

waste, scrap and sweepings of other metals" (Table 7), the percentage of EU imports to world imports amounts to 70% of the total value and that this trend is increasing substantially.

Table 7: Summary of Economic Data for Selected Trade Flows: Metals and Minerals.

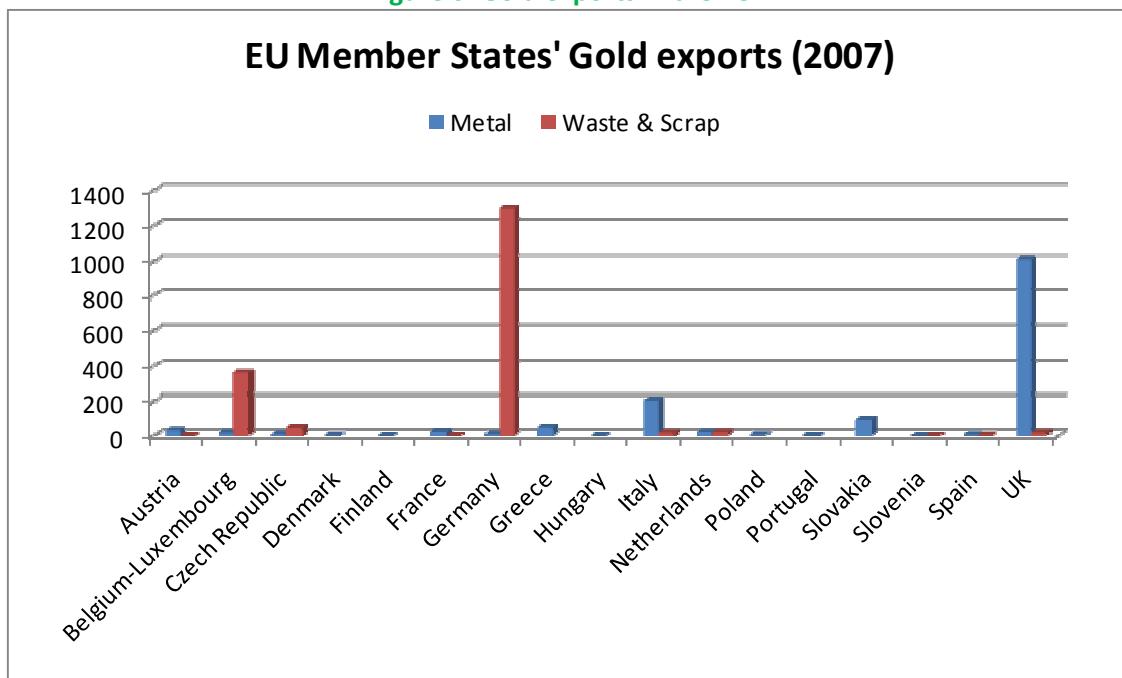
Source: Environmental Impacts of Natural Resource Trade Flows into EU²²

% of EU Imports to World imports (by value)	Value of Import to EU25 (million €)	Volume of Imports to EU25 (1000 Tonnes)	Overall Trend in Volume	Top Source Countries for EU (% of extra EU imports by volume)
70%	631	120	↑↑ (but volatile)	South Africa, Indonesia, Greenland

2.3.2. GOLD EXPORTS

In 2006, the volume of EU-27 exports of gold and platinum scrap gold reached 7366 tonnes. The largest exporter of gold in the EU is Germany, for waste and scrap gold. The largest gold metal exporter is the UK, most likely for spot or futures trading (Figure 6).

Figure 6: Gold exports in the EU²¹



2.4. GOLD RECYCLING IN THE EU

Gold has always been recycled because of its inherent high value, and most gold can be and already is recycled. Today, at least 15% of annual gold consumption is recycled each year. The remaining 85% remains in use (i.e. it is inherited). The recycling of gold used in electronics is

²² AEA Energy & Environment, Environmental Impacts of Significant Natural Resource Trade Flows into the EU, Report to DG ENV, Issue Number 6, 2008

regulated in the EU through the WEEE Directive. UNEP (2005) estimated that 20 to 50 million tons of WEEE are generated worldwide every year²³.

2. 4. 1. SOURCES OF GOLD

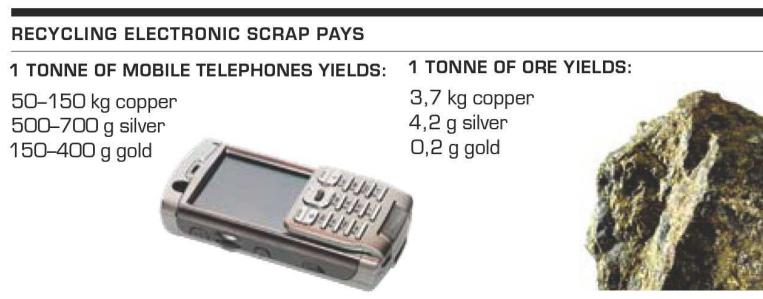
There are many different sources of gold. These include:

- Natural deposits:
 - lode and vein deposits are deposits where gold is found in cracks in rocks.
 - placer deposits are formed by moving water that has eroded gold out of lode deposits. When the speed of the water in a river slows sufficiently, the heavy gold falls to the bottom and accumulates in the sand of the riverbed²⁴.
- By-products of mining: gold is found as a by-product of copper and silver mining, recovered from copper and silver ore.
- Jewellery (e.g. wedding rings)
- Electronics
- Dentistry (e.g. dental bridges)
- Award medals
- Coins

2. 4. 2. RECYCLING POTENTIAL IN THE EU

It is estimated that 5000kg of ore are needed to mine one gram of gold, versus a mere 5kg of discarded telephones. Figure 7 illustrates the amount of gold that can be obtained from recycling one tonne of mobile telephones versus one tonne of ore.

Figure 7: Gold obtained from recycling mobile telephones.
Source: Boliden's Sustainability report (2007)²⁵



Worldwide, 3 percent of the gold and silver is used annually to make mobile phones and computers. The gold is used on the circuit boards within mobile phones and silicon chips are placed with the gold to prevent corrosion. In China, four tonnes of gold are used to make

²³ United Nations Environment Programme (UNEP) (2005), E-waste, the hidden side of IT equipment's manufacturing and use. Environment Alert Bulletin

²⁴ Information from the Mineral information institute, Accessible at : www.mii.org/Minerals/photogold.html, retrieved March 11, 2010

²⁵ Figure provided by Gavin Mudd, from Boliden's 2007 sustainability report. Boliden operate one of the largest eWaste recycling smelters in Europe.

mobile telephones and computers each year. The gold is worth around €100 million, equivalent to the monthly output of many gold producing nations²⁷.

In Western Europe it is thought that customers typically discard and replace their phones every 12 months²⁸. In Great Britain, every year, over 15 million handsets are thrown away and end up at landfill sites, and estimated to amount to over 600 kilograms of gold and silver with a value of around £6 million (or €6.7 million). Only 2% of all disposed mobile telephones in the UK are recycled efficiently²⁹.

In Germany, about 24 million mobile phones are thrown away each year, i.e. almost one for every three residents. Norddeutsche Affinerie AG is forging gold bars out of the electronic waste from German mobile phones and PCs, recovering about 3.5 tonnes of gold every year. Umicore SA near Antwerp in Belgium equally recovers about 6 tonnes of gold a year from waste. The discarded electronic equipment in Germany in 2006 amounted to 750,000 tonnes, of which 102,000 tonnes was telephones, computers and printers³⁰.

The new WEE directive is currently improving existing recycling rates. The success of battery disposals has already shown that it is possible to significantly increase the recycling rate of these products. The recycling potential shows that virtually as many mobile phones and/or computers are thrown away as are made every year. Although the countries that discard the waste are not the same as those that produce the electronic equipment, this shows a strong potential for the reuse of the precious metals used in electronic equipment within Europe.

2. 4. 3. REWORKING OF MINES

According to Euromines, state-of-the-art re-working of former mining areas to recover gold represents one of the best opportunities for Member States to fund their commitments under EU law (e.g. the Water Framework and Habitats Directives) and start the process of rehabilitating areas polluted by old mine workings. There is potential to undertake such operations in many places in Europe – wherever inefficient processes from the past have left ore in the ground, or left gold in waste deposits – provided that the provisions of Directive 2006/21/EC and the International Cyanide Management Code are complied with. Reworking and re-processing can provide the economic incentive to provide modern mine closure and rehabilitation.

²⁷ Recycling Precious Metals. Treasure Trove in World's E-Waste, The *Spiegel*, Axel Bojanowski, Full article: www.spiegel.de/international/world/0,1518,679871,00.html, retrieved March 5, 2010

²⁸ Global Policy Forum article on the impacts of cell phones, Accessible at: www.globalpolicy.org/component/content/article/181/33642.html, retrieved March 31, 2010

²⁹ Ezine articles, Mobile Phones not being Recycled, Accessible at: ezinearticles.com/?Mobile-Phones-Not-Being-Recycled---Over-600kg-of-Gold-and-Silver-Being-Thrown-Away&id=2155630, retrieved March 31, 2010

³⁰ The Jerusalem Post, "German 'Pot of Gold' lies in mobile phones tossed in the trash" 05/03/2009, Accessible at: www.jpost.com/Home/Article.aspx?id=134895, retrieved March 31, 2010

2.5. POSSIBLE ECONOMIC CONSEQUENCES OF A BAN ON GOLD EXTRACTION ACTIVITIES IN THE EU

None of the EU Member States are big gold producers, compared to China, Australia, the USA and South Africa, and therefore it could be argued that a ban would have little effects economically across the EU – though there would of course be localised economic impacts.

2.5.1. EU GOLD MINES USING CYANIDE

A number of mines using cyanide for gold extraction currently exist in the EU and several projects are being developed.

Table 8: Gold mines in the EU using cyanide³⁴

Country	Mines
Sweden	<ul style="list-style-type: none"> 2 active gold mines, Boliden and Svartliden, both use cyanide. Svartliden was granted all necessary permits in 2005. 3 non-ferrous metal mines from which gold is produced as a by-product
Finland	<ul style="list-style-type: none"> 5 - Kittilä, Orivesi, Pahtavaara, Pampalo, Vammala – all using cyanide
Spain	<ul style="list-style-type: none"> A project to re-open an existing gold mine – using cyanide
Romania	<ul style="list-style-type: none"> The largest gold deposit in Europe (Rosia Montana with estimated 330t) 2 projects (Baia Mare, Certej) 2 operating gold mines (Hanau and Romaltyn)
Bulgaria	<ul style="list-style-type: none"> The Chelopech Mining cyanide project has recently been approved for cyanide gold leaching The Ada Tepe gold mine near the town of Krumovgrad is proposed by the Canadian company Dundee Precious Metals (DPM) with its Bulgarian branch Balkan Mineral and Mining (BMM). This project is the first step in the development of open-pit gold mining with the use of cyanide leaching in the East Rhodopi mountains region – which is hoping to base its development on organic agriculture and ecological tourism. The project has met strong opposition from the citizens of the Krumovgrad municipality³².

2.5.2. THE NGO PERSPECTIVE

The international « Goldbusters coalition » is an international coalition of over 50 non governmental organisations from Argentina, Australia, Canada, Columbia, Ecuador, El Salvador, Germany, Ghana, Indonesia, Pakistan, Russia, Slovakia, the UK, Uruguay, the USA, and Venezuela³³. The coalition launched a campaign to ban the use of cyanide leach mining

³² Article on the Ada Tepe gold mine, Bulgaria, from CEE bankwatch network. Further details accessible at : <http://www.bankwatch.org/project.shtml?w=147579&s=368448>, retrieved March 31,2010

³³ The full list of participant NGOs from each country is accessible at : www.rainforestinfo.org.au/gold/members.html, retrieved March 11, 2010

technologies, in particular with the use of cyanide. In their statement of unity, they state that it is the responsibility of governments of countries where the multinational corporations come from to hold them accountable, wherever they operate, to their domestic environmental and social protection requirements. Shareholders and investors in gold mining companies must be held responsible for their corporation's actions.

It is believed that known reserves could provide for market demand. The current trend to sell gold reserves by central banks offers an alternative to gold mining to provide for market demands, but must be considered carefully in light of both social and economic ramifications. In particular, there must be transitions for workers who lose their jobs and livelihoods when gold mines close. After closure of a mine, companies have a duty and mandatory obligation for social, environmental and economic rehabilitation of the community and the miners.

2. 5. 3. THE INDUSTRY PERSPECTIVE

From the industry perspective, one immediate consequence would be the closure of existing gold exploration and mining projects and the loss of associated investments³⁴.

One related consequence would be the “opportunity cost” of preventing mineral-rich Member States from realising the benefits that others (e.g. Finland, France, Ireland, Italy, Spain and Sweden) have enjoyed from non-ferrous mining in the past – the majority of which used cyanide for their recovery of gold. Finland and Sweden continue to actively seek direct foreign investment into their mining regions and little or no investment would remain if a ban was put in place.

According to Euromines, an EU ban on the use of cyanide in the mining industry would effectively banish gold-prospecting and mining from the EU and act as an incentive to extract gold from regions of the world with less environmental controls in place. Euromines’ opinion is that a ban would be in contradiction to the Raw-Materials Policy, which is looking at resource-efficient supply of raw-materials for EU Manufacturing – in particular information and “green” technologies.

³⁴ Information provided by Johannes Drielsma (Euromines)

3. GOLD EXTRACTION TECHNIQUES

The boom in gold production is the result of an important technological revolution, the use on gold ores of an old mining technology called “heap leaching” in which chemicals are used to remove the gold from vast open-air mounds of ore. Cyanide is now the chemical choice of the gold industry throughout the world; more than 90 percent of the 2500 tonnes of annual global gold production is extracted using this chemical¹.

There are other ways to treat gold besides using cyanide, but the question very much depends on the geological provenance of the gold, the nature of the ore and how the gold is bound into the host minerals. Gold can be found in different forms, either as free gold; as gold in association with other elements such as silver, arsenic, cadmium, mercury; or in association with common sulphides such as pyrite or arsenopyrite as refractory gold. These metal associations are determined by how the mineralization formed. Over half of all known gold deposits worldwide are of the refractory kind. However, the types and quantities present in the EU are not known precisely because an EU-wide geological database has not yet been established and the whole of Europe has not been sufficiently explored – especially with the more modern exploration technologies developed over the past 30 years. The ‘Midas’ Project, or “Multi-dataset Analysis for the Development of Metallogenetic/Economic Models and Exploration Criteria for Gold Deposits in Western Europe” has been instigated, involving the earth sciences expertise of several countries. “Exploration in France, Spain, Portugal, Ireland and the UK will use multiple datasets including mineral occurrence, geological, geochemical, geophysical and remotely sensed information³⁵.

Mercury (Hg) can be used for gold extraction but in turn is highly toxic and does not biodegrade. It is used by artisanal or small scale miners, e.g. in Brazilian squatter mines, but not in any commercial large scale gold mines. Most mercury research centres on artisanal mining and associated human health and environmental impacts. There are no well-known examples of large scale mercury use in gold extraction within the EU gold industry.

3.1. GOLD LEACHING USING CONVENTIONAL CYANIDATION: BEST AVAILABLE TECHNIQUES

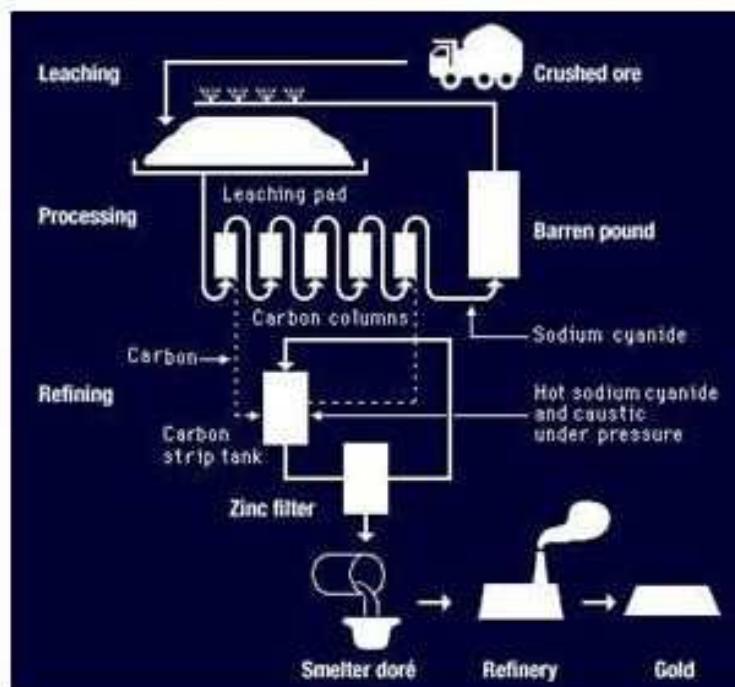
Cyanide is a lixiviant, i.e. a liquid medium used in hydrometallurgy to selectively extract the desired metal (in this case, gold) from the ore or mineral. The metal can be recovered from it in a concentrated form after leaching. The position of cyanide as the universal lixiviant for gold ores has not been seriously challenged since the development of the cyanidation process in the late 19th century.

³⁵ The ‘Midas’ Project. Further information available on the British Geological Survey website. Contact : Eur. Ing. Peter Simpson, Geocchemistry Group : Minerals & Geochemical Surveys Division.

The use of cyanide takes place in the leaching phase (Figure 8), where a slurry of ground ore, water, and a weak cyanide solution is fed into large steel leach tanks, where the gold and silver are dissolved. Following this leaching process, the slurry passes through six adsorption tanks containing carbon granules which adsorb the gold and silver.

The European Commission Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities³⁶ describes the Best Available Techniques (BATs) that are implemented in all EU operations. BATs include a cyanide destruction step which ensures that cyanides are re-used in the process and/or destroyed prior to any discharge to the tailings dam.

Figure 8: Extraction of gold using heap leaching and carbon recovery³⁷



3. 1. 1. BATs FOR GOLD LEACHING USING CYANIDE

The BATs for gold leaching using cyanide include:

- reducing the use of cyanide, by applying
 - operational strategies to minimise cyanide addition
 - automatic cyanide control
 - If applicable, peroxide pretreatment
- destroying the remaining free cyanide prior to discharge in the pond
- applying the following safety measures

³⁶ European Commission, Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities, January 2009. Accessible at :

ftp://ftp.jrc.es/pub/eippcb/doc/mmr_adopted_0109.pdf, retrieved March 10, 2010

³⁷ Heap leaching: extraction of gold using heap leaching and carbon recovery. Adapted from PAMP (Produits Artistiques de Métaux Précieux, based in Switzerland

- sizing the cyanide destruction circuit with a capacity twice the actual requirement
- installing a backup system for lime addition
- Installing backup power generators

3. 1. 2. MINIMISING CYANIDE ADDITION

Following are operational strategies to minimise cyanide addition:

- taking steps to reduce the consumption of cyanide by other components
- attempting to retain cyanide in the circuit rather than discharging it to the tailings pond
- employing a strict control of water additions to the circuit, to reduce the need to discharge the solution in order to maintain a water balance
- utilising a close monitoring of the cyanide concentration in the process and in the tailings, in order to keep cyanide addition to a minimum
- improving aeration in the leach
- applying pre-aeration of the slurried ore before cyanidation to oxidise the cyanide consuming constituents, which can then be thickened and removed from the process
- using gravity separation, if possible, and leaching the concentrate from this process

BATs also apply automatic cyanide detoxification technologies, which enable to save up to 10-20% of the cyanide compared to the manual operation, whilst achieving the same gold recovery.

3.2. GOLD LEACHING USING ALTERNATIVE REAGENTS TO CYANIDE

During the last few years, various alternative reagents have been seriously considered, such as:

- Thiosystem: thiosulfate, thiocyanate and thiourea
- Polysulfide system
- Ammonia system: ammonia and ammonium copper-cyanide³⁸
- Halide system (halides or halogens): chlorine, bromine and iodine

Stephen Gos and Andreas Rubo³⁹ suggest that gold lixiviants should be economical, universally applicable on most ore types and safe to transport, handle and detoxify or recycle, based on the following criteria:

- Economics: Capital investment; Extraction economics; Availability; Costs considering detox/recycling
- Process applicability: Limitations (e.g. ore type, selectivity, control, separation); Recyclability; Detoxifiability; Large scale applications

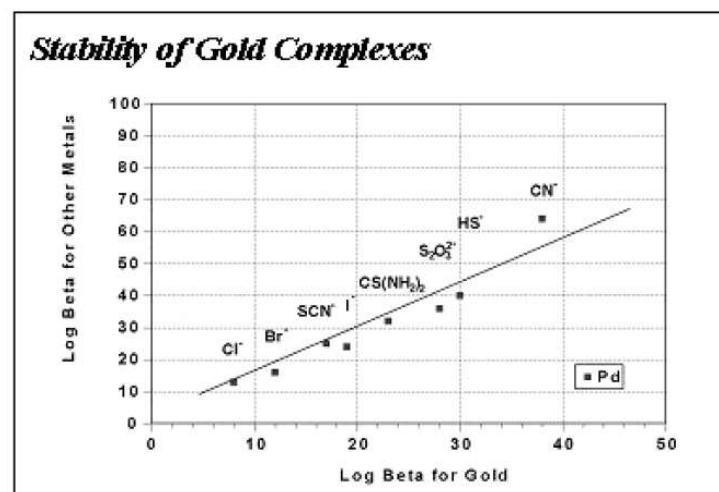
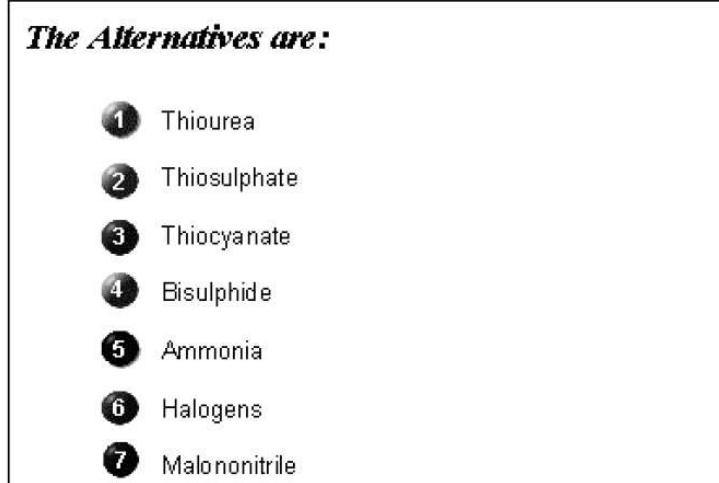
³⁸ Wan, R. Y., Miller, J. D., and Li, J., 2005. Thiohydrometallurgical Processes for Gold Recovery. Innovations in Natural Resource Processing, Proceedings of the Jan. X Miller Symposium, Society for Mining, Metallurgy, and Exploration, Inc., Littleton, CO: 223-244.

- Toxicity: Emissions; Handling; Environmental toxicology

Most alternative lixiviants are more hazardous and persistent than cyanide (Figure 9 and Figure 10). Furthermore, they form less stable complexes with gold and thus require more aggressive reagents to dissolve the gold.

According to Euromines, there are only four alternatives that have the potential of cyanide replacement: ammonium-thiosulfate, thiourea, halide leaching (bromine-bromide, chlorine-chloride), and bio-leaching. The only system to have been seriously considered in the last few years is ammonium-thiosulfate. Because of the higher cost of these alternative systems and their lack of efficiency compared to cyanide, it was said that the cyanide systems proved to be the safest chemical extraction system for recovering gold.

Figure 9: List of alternative lixiviants and stability of the gold complexes³⁹



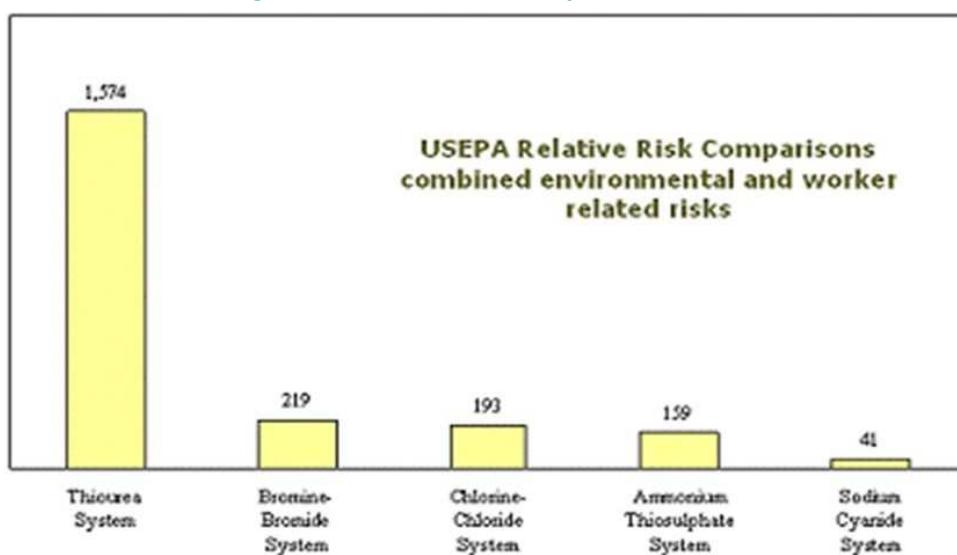
³⁹ Stephen Gos, Andreas Rubo, The relevance of alternative lixiviants with regard to technical aspects, work safety and environmental safety, Degussa AG, Hanau, Germany, prepared by CyPlus® - written by cyanide producers

Figure 10: Alternative lixiviants to cyanide⁴⁰

Alternatives to cyanide					
Reagent type or trade name	Concentration range	pH range	Basic chemistry	Research level	Extent of commercialisation
Ammonia	High	8-10	Simple	Low	Pilot tests, +100°C
Ammonia/Cyanide	Low	9-11	Simple	Extensive	Applied to Cu / Au ores
Ammonium thiosulphate	High	8.5-9.5	Complex	Extensive	Semi-commercial
Slurry CN-electrolysis	Low	9-11	Simple	Historical	Limited historical
Sodium sulphide	High	8-10	Simple	Low	Geological interest only
Alpha-hydroxynitriles	Moderate	7-8	Fairly simple	Fairly popular	None
Malononitrile	Moderate	8-9	Fairly complex	Low	None
Alkali cyanoform	Poorly defined	9(?)	Poorly defined	Low	None
Calcium cyanamide	Poorly defined	9(?)	Poorly defined	Low	None
CSUT(1)	High	9-10	Complex	Very low	None. KMnO ₄ is oxidant
Alkaline polysulphides	High	8-9	Poorly defined	Low	None
Biocatalysed bisulphide	Poorly defined	8-10(?)	Poorly defined	Low	None
Hypochlorite /chloride	High chloride	6-6.5	Well defined	Extensive	Historical and modern
Bromocyanide	High	6-7	Poorly defined	Historical	Historical
Iodine	High	3-10	Poorly defined	Low	None
Bisulphite/sulphur dioxide	High	4-5	Fairly simple	Low	None
Bacteria	High	7-10	Fairly complex	Low, growing	None
Natural organic acids	High	5-6(?)	Fairly complex	Low	None
DMSO, DMF	Poorly defined	7(?)	Poorly defined	Very low	None
Bromine/bromide	High	1-3	Well defined	Low	Historical
Thiourea	High	1-2	Well defined	Fairly popular	Some concentrates
Thiocyanate	Low	1-3	Well defined	Low	None
Aqua regia	High	below 1	Well defined	Low	Analytical and refining
Acid ferric chloride	High	below 1	Well defined	Low	Electrolytic Cu slimes
Ethylene thiourea	High	1-2	Poorly defined	Very low	None
Haber process	Poorly defined	?	Proprietary	1 entity	None
'Bio-D leachant'	Poorly defined	?	Proprietary	1 entity	None
High temp chlorination	High	6-7	Simple	Historical	Historical

The USEPA along with Purdue University developed a risk-based assessment scheme that took into account various environmental, toxicity, and worker related data for a long list of chemicals that are widely used throughout the world. From the data, cumulative risks to the environment and workers were tabulated for each lixiviant system presented as a substitute for cyanide (Figure 11 and Figure 12).

Figure 11: Gold extraction systems



⁴⁰ By Dr. Terry McNulty, P.E., for MINING Magazine, May 2001 (article available)

Figure 12: Toxicity of alternative lixiviants

Lixiviant	Toxicity dose	TLV - or MAK, German equivalent	Toxicity - concentration value	WGK				
Thiourea	LD50 125 mg/kg carcinogen	-	LC50 >100 g/L	2	Ammonia	LD50 350 mg/kg	14 mg/m ³	LC50 0.53 mg/L/96 h
Thiocyanate	LD50 764 mg/kg	-	-	1	Bromine	LD10 14 mg/kg	0.6 mg/m ³	LC100 10 mg/L/10h
Thiosulphate (ammonium)	LD50 2890 mg/kg	-	Consider ammonia	1	Chlorine	LC50 293 ppm/h	1.5 mg/m ³	LC10 0.05 mg/L/96h
Bisulphide (based on H ₂ S)	LC50 15 mg/m ³ 1500 mg/m ³ /14 minutes (rat)	15 mg/m ³	LC50 1500 mg/m ³ /7 min (fly)	2	Iodine	LD50 14000 mg/kg	1.1 mg/m ³	LC50 0.16 mg/L
					Cyanide, sodium	LD50 6.4 mg/kg	5 mg/m ³ as CN, approx 10 mg/m ³ as sodium cyanide equivalent	LC50 0.083 mg/L/96h
					Cyanide, hydrogen	LD50 3.7 mg/kg	5 mg/m ³ as CN	LC50 2.29 mg/L/96h

3. 2. 1. THIOSYSTEM (THIOSULPHATE, THIOUREA, THIOCYANATE)

(Ammonium-)Thiosulphate is much less toxic than cyanide and can biodegrade, but it is relatively inefficient for gold extraction. There are various research programs into thiosulfate, though not of a very large scale. Australia's research agency, CSIRO, has done a lot of work on thiosulphate over the years (still very small compared to their cyanide leaching research), but have never been able to find a breakthrough to make thiosulphate both technically efficient and economically attractive for the wide variety of gold ores known⁴¹. Thiosulphate (and ammonium-thiosulphate) has high a high consumption of reagent and is possibly suitable for carbonaceous ores or ores with high soluble copper

Thiourea has been reported to have leaching rates 10 times faster than cyanide, but the selectivity for gold is questionable, since thiourea is intrinsically unstable and decomposes rapidly to substances that are unable to leach gold. Thiourea has a toxicity profile that is no more favourable than cyanide. Recovery of gold from the solution requires further research, since a lower thiourea concentration will be required to make it economically viable.

Thiocyanate may be suitable for most ore types and the recyclability could be possible if the temperature is not too high to decompose to a considerable extent. In practice, high temperature around 85°C is necessary to achieve satisfactory leach performance. The costs would be considerable since five moles of active oxygen are required per mole of thiocyanate to oxidise it to sulphate and cyanate. However thiocyanate is only classified as a slight water contaminant and the ecotoxicity data is quite favourable.

3. 2. 2. POLYSULPHIDE SYSTEM

Hunter et al.⁴² of YES Technologies described a bisionary process using bisulphide as a lixiviant for gold. The extremely long retention times and closed system that would probably be required would mean high capital investment costs for such a leach plant. However, the

⁴¹ Information provided by Gavin Mudd

⁴² Hunter R. et al. (1999). Vol 12, No. 6, pp 645-653

availability and reasonable price of bisulphide and its sources indicate reasonable extraction economics because hydrogen sulfide is regenerated from sulphate using bacteria. The operating costs considering detoxification however would be high, because a chemical oxygen demand would be necessary. One major drawback is the generation of hydrogen sulfide. Bisulphide itself is a water contaminant.

3. 2. 3. AMMONIA SYSTEM

Xinghui et al.⁴³ have described the use of ammonia as a lixiviant for refractory ores at temperatures between 100 and 300°C and 1.7 to 7.9 bar. The use of ammonia is more commonly known as an additional reagent in cyanidation for cooper-containing orebodies. Fast reaction times of 2-4h were reported for 88-95% recovery. However, the high temperatures and pressures required would indicate high capital investment for a leach plant of this type. Ammonia would have to be a closed system to avoid the release of ammonia. Ammonia may eventually be broken down to nitrate in the environment by bacterial oxidation, but this is a slow process. The economic viability seems to be the limiting factor in this process.

3. 2. 4. HALIDE SYSTEM (CHLORINE, BROMINE AND IODINE)

Halides are salts of halogen elements such as chlorine, bromine and iodine. Chlorination was used before the introduction of cyanide. Halide leaching was used at several plants in the USA in the 1980s. The most notable research in recent years is the MinataurTM process developed by MINTEK⁴⁴. Halide consumption can be very high for sulphidic ores⁴⁵.

⁴³ Xinghui et al. (1993). Hydrometall. Proc. Milton E. Wadsworth, Int. Symp. 4th, pp205-221

⁴⁴ Feather et al. (1997), information provided by Johannes Drielsma (Euromines)

⁴⁵ Adams et al., information provided by Johannes Drielsma (Euromines)

Table 9 provides a comparative analysis of the advantages, disadvantages, costs and efficiency of alternative reagents.

Table 9: Comparative analysis of advantages, disadvantages, costs and efficiency of alternative reagents³⁹

Lixiviant	Possible advantages	Possible disadvantages	Costs & extraction economics	Efficiency
Thiosystem				
Thiourea	<ul style="list-style-type: none"> Proven technology Availability Suitable for refractory ores Consumption has been reduced by redox control Fast rate of gold dissolution 	<ul style="list-style-type: none"> Limited recyclability (decomposition) Detoxification costs would be considerable Difficult to control process parameters Limited applicability Suspected carcinogenic compound Water contaminant Release of H₂S and BH₃ in higher quantities is possible. 	<ul style="list-style-type: none"> Capital costs similar to that of a cyanidation plant, although more expensive tanks (stainless steel) for lower pH reasons. Extra costs for ferric sulphate and acidic Operating costs considerably higher because of the high oxygen demand for full oxidation 	<ul style="list-style-type: none"> High reagent consumptions: up to 47kg thiourea/t ore Consumptions as low as 0.5kg thiourea/t ore using SO₂ as a reducing agent Higher demand of thiourea compared to cyanide.
Thio-sulphate	<ul style="list-style-type: none"> Proven technology Availability Suitable for refractory/pre-robbing ores not amenable to cyanidation Good leach performance (e.g. >99%) 	<ul style="list-style-type: none"> Recyclable only to limited extent due to instability Control difficult Limited applicability 	<ul style="list-style-type: none"> Capital costs similar to that of a cyanidation plant Availability high and reasonable in price Detoxification by oxidation would increase operating costs significantly 	<ul style="list-style-type: none"> High reagent consumptions: up to 48.6 kg/t ore However, consumptions of 5kg/t ore on a carbonaceous (both as ammonium thiosulphate)
Thio-cyanate	<ul style="list-style-type: none"> Can act as a lixiviant over a wide pH range Recyclable (partly) 	<ul style="list-style-type: none"> Availability limited No large scale applications known Detoxification costs would be considerable Higher temperatures required 	<ul style="list-style-type: none"> Higher temperatures for leaching indicate that high capital costs would be required for a leach plant, and higher operating costs compared to cyanidation. 	
Polysulfide system				

Lixiviant	Possible advantages	Possible disadvantages	Costs & extraction economics	Efficiency
Bi-sulphide	<ul style="list-style-type: none"> • Availability • Reasonable price and sources = reasonable extraction economics (since is regenerated from sulphate using bacteria) • Recyclable 	<ul style="list-style-type: none"> • Extremely long retention times and a closed system would be required – high capital investment costs • Operating costs for detoxification would be high (chemical oxygen demand) • Solely suitable for bio-oxidised ore • H₂S is generated • Biosulphide is a water contaminant 	<ul style="list-style-type: none"> • Long retention times and probably high capital costs would lead to the economic viability being much less favourable than that of cyanide. 	
Ammonia system				
Ammonia	<ul style="list-style-type: none"> • Availability • Recyclable • Could be suitable for refractory ores 	<ul style="list-style-type: none"> • No large scale applications known • Not detoxifiable: must be recycled • Requires high temperatures and pressures for acceptable leach performance • Selectively doubtful 	<p>High temperatures and pressures would indicate high capital investment and high operating costs for a leach plant of this type</p>	<p>Fast reaction times of 2-4 hours for 88-95% recovery</p>
Halide system				
Halides/ Halogens (Bromide, chloride and iodide)	<ul style="list-style-type: none"> • Proven technology • Availability • Universal applicability for most ore types • Leach performance is good 	<ul style="list-style-type: none"> • Handling and control is difficult • Requires oxidant, mostly halogen or halide itself 	<ul style="list-style-type: none"> • For bromide and chloride, the extraction economics are reasonable, but the use of an oxidant would lead to higher capital investment costs for the prevention of corrosion and the use of a closed system. 	

The following lixiviant profile chart is based on the various criteria that should be considered in comparing gold lixiviants with cyanide (Table 10).

Table 10: Lixiviant profile chart

	Economics				Process applicability				Toxicity		
	Capital investment	Extraction economics	Availability	Costs for detox/recycling	Limitations (ore type, selectivity, control, separation)	Recyclability	Detoxification	Large scale applications	Emissions	Handling	Environmental toxicology
Thiourea											
Thiosulphate											
Thiocyanate											
Bisulphide											
Ammonia											
Halogens											
Maloninitrile											
Cyanide											

Favourable		Acceptable		Not Favourable	
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3. 2. 5. BIO-LEACHING

Bio-leaching uses bacteria to oxidise refractory sulphide ore. They act as a catalyst to speed up the natural processes inside ore, oxidising refractory sulphide ore. This turns metal sulphide crystals into sulphates and pure metals. The constituent parts of ore are separated into valuable metal and leftover sulphur and other acidic chemicals. Eventually, enough material builds up in the waste solution to filter and concentrate it into metal.

Bio leaching is a simple, effective, and low cost method. For metals such as copper, bioleaching is not always economically feasible or fast enough, yet about 20% of the extracted copper in the world currently comes from bioleaching. However, pollution might result if solutions reach a groundwater source. Yet overall, bioleaching produces less air pollution and little damage to geological formations, since the bacteria occur there naturally. An ideal metal deposit must allow a certain amount of water into the rock to carry the bacteria. However, it should be surrounded by rock that is impermeable to water to make sure no ground water gets polluted with sulphur.⁴⁶

⁴⁶ Information obtained from the Wisegeek website, What is Bioleaching ?, Accessible at : www.wisegeek.com/what-is-bioleaching.html, retrieved March 10, 2010

Attia et al. investigated the feasibility of pre-treating the refractory tailings with bioleaching before using standard extraction techniques such as cyanidation⁴⁷. Nicholas S. Lynn also described the use of biooxidation techniques in gold-processing mills to achieve economical recovery from refractory ores⁴⁸.

Numerous ferrous and sulphur oxidising bacteria are used to extract gold from its ore. The bacteria catalyse the breakdown of the mineral arsenopyrite by oxidising the sulphur and metal to higher oxidation states. This separates the gold from the ore. Bio-leaching could make the ore amenable to normal oxide ore processing techniques.

BioMinE (Biotechnologies for Metal bearing materials in Europe) is an Integrated Project in the Sixth Framework Programme that will allow the integration of innovative biotechnology based processes for recovery and/or removal of metals from primary materials (ores and concentrates) and secondary materials (including mining wastes)⁴⁹. The initial screening of the mineral deposits has retained copper, zinc, and refractory gold deposits as principal targets for the BioMinE project. Screening for economic feasibility addresses 778 sites with gold as main commodity or by-product⁵⁰.

3. 2. 6. NEW RESEARCH

David H. Creasey and Edwin B. Smith Jr have filed an international patent in April 2009 entitled “Metal extraction without cyanide”⁵¹ for the invention of a process and composition effective for extracting precious metals including gold, and more specifically, a lixiviant composition and process that is not an irritant or deleterious to humans and the environment, and suitable for replacing toxic cyanide compounds currently used in extracting metals from metal-containing ore. Their process comprises the following steps: a) selecting a metal-containing ore; b) crushing the metal-containing ore to form a powder; c) conveying the powder to a mixing vat; d) adding an amount of a three-component lixiviant that consists of a liquid that is not an irritant or deleterious to humans and the environment, consisting essentially of, low pH acidic composition (LpHAC), an alkali metal salt and water to form an aqueous slurry; e) extracting metals from the slurry to form a pregnant liquid and a solid residue; f) conveying the pregnant liquid and solid residue to a solid/liquid separator; g) removing solids from the pregnant liquid and solid residue of step e); h) directing the pregnant liquid of step g) to a metal recovery unit; and i) collecting a high purity metal.

⁴⁷ Attia et al., Bioleaching of gold pyrite tailings with adapted bacteria, *Hydrometallurgy*, 1989 (Available on Elsevier)

⁴⁸ Nicholas S. Lynn, The bioleaching and processing of refractory gold ore, *Journal of the Minerals, Metals and Materials Society*, Volume 49, Number 4 / avril 1997

⁴⁹ The Biomine project details are accessible at: biomine.brgm.fr/about_about.asp, retrieved March 10, 2010

⁵⁰ European Metal Deposits in the BioMinE Project – Wealth Creation Through the Development of Biohydrometallurgy, Andor L.W.Lips (BRGM) and the BioMinE consortium.

Accessible at : biomine.brgm.fr/Documents/5Pressroom/Pressreleases/48a_SEG_Lips_abstract_final.pdf, retrieved March 10, 2010

⁵¹ Accessible at : www.wipo.int/pctdb/en/wo.jsp?WO=2009120373&IA=US2009001928&DISPLAY=STATUS, retrieved March 11, 2010

3.3. CARBON-EXTRACTION PROCESSING

Carbon can be used in two different ways:

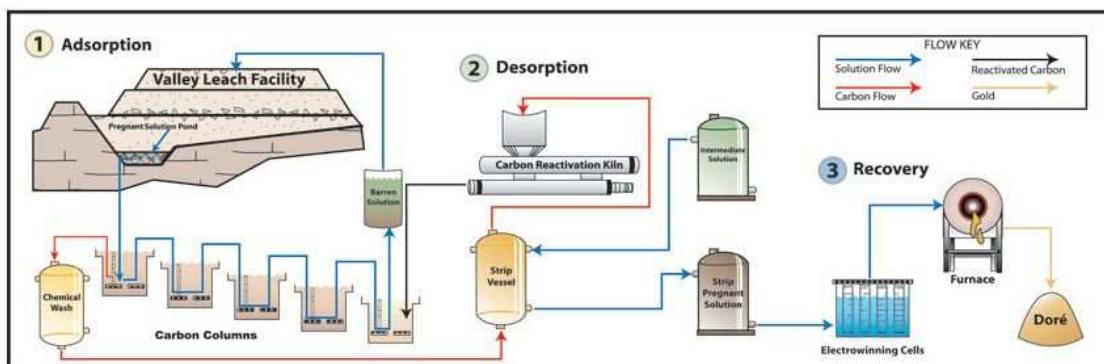
- Without cyanide, to separate non refractory or more easily liberated gold
- In combination with cyanide, for cyanide leaching, which is particularly successful in extracting refractory gold

Activated carbon adsorbents are employed in many cyanidation plants to recover gold and silver from cyanide leach solutions from several processes: carbon in pulp (CIP), carbon in leach (CIL) and carbon in column (CIC). Activated carbon is a highly porous material with distinct adsorptive properties. Gold complexes with either chloride or cyanide are strongly adsorbed by activated carbon. The process usually comprises the following operations: extraction, elution, electrowinning, and thermal reactivation.

The concentration of gold using carbon takes place in three main phases (Figure 13)⁵².

- Adsorption: The process solution containing the dissolved gold and silver is pumped from the Valley Leach Facility (VLF) to the recovery plant, where it passes through cascading carbon columns. This is where the gold and silver adsorb or attaches to the surface of the carbon.
- Desorption: The gold and silver are chemically removed or desorbed from the carbon, creating a concentrated solution
- Recovery: The dissolved gold and silver are removed from the concentrated solution via electrowinning cells.

Figure 13: The concentration of gold using carbon⁵²



The following are common non-cyanide methods for treating non-refractory gold

3.3.1. CARBON IN COLUMN

Carbon-in-Column circuits are employed to recover gold from pregnant heap-leach solutions by adsorption of the precious metals onto fine carbon suspended by up-flow of solution through a tank. This might be used to recover by-products from a non-ferrous metal mine (e.g.

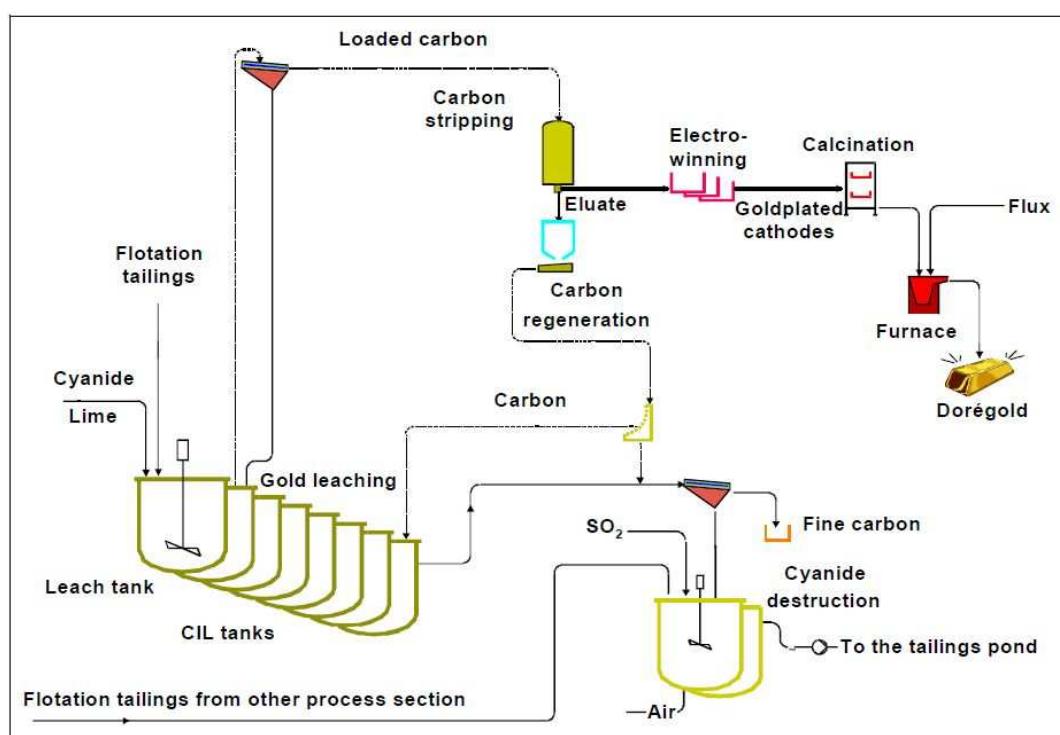
⁵² Information obtained from the Cripple creek & Victor gold mining company, Accessible at : ccvgoldmining.com/Operations/Recovery/goldrecoverysign.htm, retrieved March 10, 2010

copper). Heap leaching is used as a low capital and operating cost method of recovering gold from low grade surface deposits and waste rock. The process involves building heaps of crushed and agglomerated ore and dripping sodium cyanide solution through the heap to leach the gold into solution.

3.3.2. CARBON IN LEACH

A method of recovering gold and silver from fine ground ore by simultaneous dissolution and adsorption of the precious metals onto fine carbon in an agitated tank of ore solids/solution slurry. The carbon flows counter currently to the head of the leaching circuit. This method is commonly combined with cyanidation for recovery of refractory gold.

Figure 14: The Carbon-in-leach process. Source: Au group⁵³



3.3.3. CARBON IN PULP

A method of recovering gold and silver from fine ground ore by adsorption of the precious metals onto fine carbon in an agitated tank of ore solids/solution slurry. This recovery step in the process follows the leaching process which is done in similarly agitated tanks, but without contained carbon. This method is commonly combined with cyanidation for recovery of refractory gold.

⁵³ Au group, E. (2002). « Contribution gold, Swedish mining industry (Boliden) Euromines.

3.4. ENVIRONMENTAL PROTECTION: CYANIDE DESTRUCTION, RECYCLING AND REMEDIATION

3.4.1. CYANIDE DESTRUCTION

A range of different techniques exist for the destruction of cyanides in wastewater. The European Commission Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities³⁶ recommends the controlled destruction of cyanide in tanks, e.g. using a new technique that combines the use of the sulphur dioxide technique (applicable to slurries) and the hydrogen peroxide technique (not applicable to slurries). “The benefit of this new technique is its flexibility to accommodate changes in feed chemistry. Depending on site-specific conditions, the process offers capital and operating savings over traditional SO₂/air plants”.

Natural degradation results from a combination of physical, chemical and biological processes, including volatilisation, photodecomposition, hydrolysis and adsorption on solids. Of these mechanisms, volatilisation is considered to be the most important.

Chemical treatments can be used; the choice of the treatment depends on the nature of the cyanide compound, as only oxidizable cyanides can be treated by chlorine dioxide or other oxidants⁵⁴.

- Hydrogen peroxide is the most common oxidant and can be catalysed by the presence of copper.
- The INCO process (using SO₂) oxidises cyanide and thiocyanate anions into cyanate.
- SART: Sulphidisation, Acidification, Recycling and Thickening
- Chlorine dioxide is used at moderately basic pHs and destroys cyanide complexes containing Ag⁺, Cu⁺, Zn²⁺, Ni²⁺, Pb²⁺, and Cd²⁺.
- Alkaline chlorination is effective for oxidation of all cyanides except iron complexes, noble metal, and cobalt complexes.

3.4.2. RECYCLING USING MEMBRANE TECHNOLOGY

The recycling of cyanide using membrane technology, which is currently under development, is planned to be applied to the gold metallurgical extraction process, where the efficacy of cyanide use is hindered due to the presence of copper (and similar metals such as zinc and silver). The presence of these metals causes an increase in the consumption of cyanide, a lowering of the gold recovery efficiency, and also poses a heightened environmental management issue for the tailings. The technique is described in detail in the Best Available Techniques document on mining waste management³⁶

⁵⁴ Information provided by the Minerals Council of Australia Fact Sheet on Cyanide destruction processes (March 2005), Accessible at :

www.minerals.org.au/_data/assets/pdf_file/0005/8717/cyanide_destruction.pdf, retrieved 24 March 2010

There are obvious environmental benefits to this: the amount of cyanide and copper in the tailings stream is reduced significantly prior to cyanide destruction or disposal of the waste to tailings storage facilities.

3.4.3. RECYCLING USING ION EXCHANGE RESINS

Ion exchange resins can potentially be applied in cyanide recycling to address growing environmental concerns over the use of cyanide during gold extraction. J.C. Riani et al. demonstrate why cyanide recycling is considered an alternative, especially in the plants treating high-cyanide-consuming ores such as those of gold-silver. Cyanide can be recovered from either pulps or clarified solutions. In both situations, ion exchange resin can be used as a step to concentrate the cyanocomplexes present in the effluents, facilitating recycling. Unlike activated carbon, ion exchange resins load not only gold cyanide, but also all metallic cyanocomplexes. Furthermore, resins are not poisoned by organic matter and do not adsorb calcium magnesium or silica, as does activated carbon. As they are insoluble in aqueous phase, resins are ideal to load base metal cyanocomplexes at low concentrations⁵⁵.

Virginia Ciminelli⁵⁶ describes the characteristics that make ion exchange resins attractive compared to activated carbon: fast loading rates, potentially higher loading capacity, and the lack of need for thermal activation. They are also less affected by the presence of naturally occurring carbonaceous matter or organic reagents. Ion exchange resins can be used in 3 main contexts in gold metallurgy:

- For the concentration and recovery of gold from leach pulps or solutions. The resins are in this case an alternative to activated carbon, the typical gold adsorbent from dilute cyanide solution
- For cyanide recovery from barrens. This procedure is strongly motivated by the increasing environmental restrictions on the use of cyanide. Recovery decreases the risk of spills by reducing the transport of new reagent and cyanide loading in tailing ponds
- For gold recovery from non-cyanide leach pulps

3.4.4. PHYTOREMEDIATION OF CONTAMINATED SOILS, SEDIMENTS AND WATER

Wastewater treatment with constructed wetlands, i.e. wetland-phytoremediation, is one possible route for minimising the environmental impact of emissions from gold mining. Phytoremediation is the use of green plants to stabilise or remove contaminants from soils, sediments or water³⁶. The goal of an ongoing research project is to find high biomass plants that combine a sufficiently high uptake of cyanide with low susceptibility towards cyanide as

⁵⁵ J.C. Riani et al., The elution of metal cyanocomplexes from polyacrylic - and polystyrene- based ion exchange resins using nitrate and thiocyanate eluants, Brazilian Journal of Chemical Engineering, Braz. J. Chem. Eng. vol.24 no.3 São Paulo July/Sept. 2007. Accessible at: www.scielo.br/scielo.php?pid=S0104-66322007000300011&script=sci_arttext, retrieved March 11, 2010

⁵⁶ Virginia ST Ciminelli, Ion exchange resins in the gold industry, JOM (Journal of the Minerals, Metals and Materials Society), Springer Boston, 2007. Accessible at: findarticles.com/p/articles/mi_qa5348/is_200210/ai_n21319044/, retrieved March 10, 2010

well as towards toxic metals. The aim is to establish field-scale experiments in model wetlands in order to develop a bioremediation technology for industrial use⁵⁷.

⁵⁷ Prof. Dr. Andreas Schaeffer, University of Technology Aachen (RWTH Aachen), Germany, Biology V – Environmental Chemistry

4. CONCLUSIONS AND RECOMMENDATIONS

There are currently increasing concerns about the use of cyanide for gold extraction in the EU mining industry, following recent accidents in Sweden, Romania, Spain, and Italy. These accidents have followed the storage of cyanide residues in tailing dams where there was no cyanide destruction step within the process plant.

EU gold mining production remains a finite fraction of the overall world production, since the six main gold producing EU Member States, Sweden, Finland, Hungary, Italy, Romania and Bulgaria account for less than 1% of the total world gold production. However, given the potential toxicity of cyanide it would seem necessary to control the use of cyanide in order to prevent any leaching into soil and ground water.

4.1. ALTERNATIVES TO CYANIDATION

A number of different gold extraction techniques exist, but conventional cyanidation remains by far the most widely used technique because of its cost-effectiveness. Added to this, many of the alternative leaching techniques pose equal risks to the environment.

Existing alternatives to cyanide leaching include techniques based on carbon extraction, i.e. carbon-in-leach, carbon-in-pulp and carbon-in-column. These techniques are generally used for « free » ores. To implement these technologies it would be necessary to determine what proportion of free ores are to be found in the EU. It remains also to be seen whether bio-leaching and new techniques can be used for gold extraction as these have not yet been implemented on a wide scale.

4.2. COSTS OF EXTRACTIVE TECHNIQUES

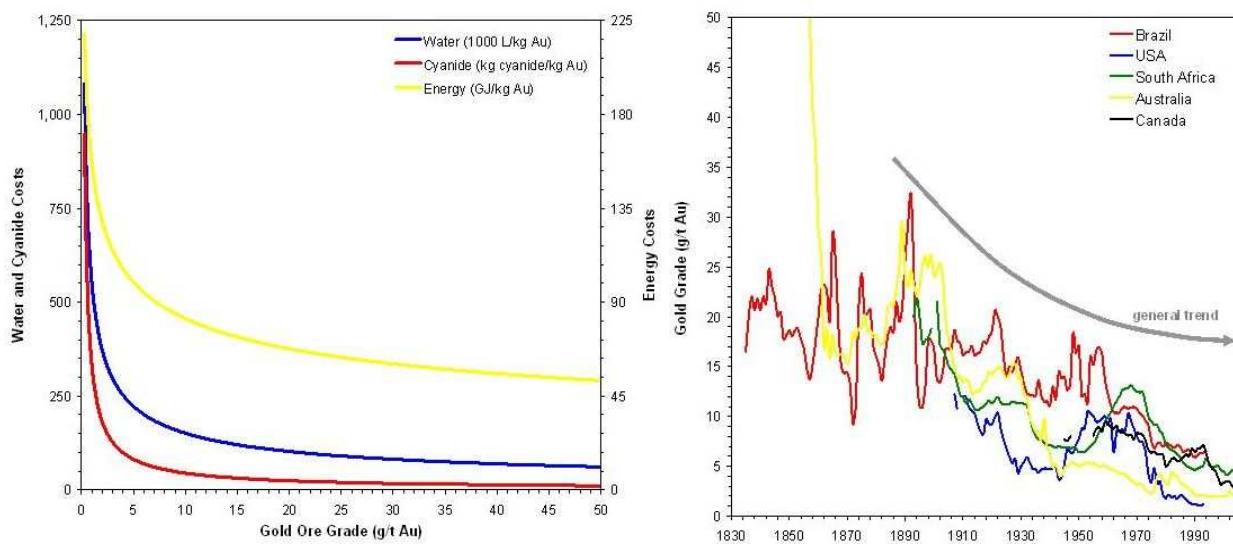
General trends reveal that the unit environmental costs of gold production are currently increasing, both in terms of energy, water and cyanide inputs and in terms of greenhouse emission outputs. The ore grade, or amount of gold contained per tonne of rock mined, determines the potential for a gold ore to be mined economically as well as potential costs⁵⁸. When compared to the general relationships for the energy, water and cyanide required to produce a kilogram of gold ore (Figure 15), it is clear that the unit environmental costs of gold production will start to increase substantively in the near future given the long-term decline in ore grades.

⁵⁸ Mudd, Gavin (Lead Author); Cutler J. Cleveland (Topic Editor). 2008. "Gold mining and sustainability: A critical reflection." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [Last revised September 12, 2008; Retrieved March 5, 2010]. Accessible at:

www.eoearth.org/article/Gold_mining_and_sustainability:_A_critical_reflection, retrieved March 9, 2010

Figure 15: Energy, water and cyanide consumption per gold produced vs Gold ore grade, compared to the Gold ore grades for selected countries over time.

Source: G Mudd et al. 2008. "Gold mining and sustainability: A critical reflection."⁵⁸



The costs of the different gold extraction techniques cannot be directly compared however, because the costs depend intrinsically on the capacity of the plant, larger plants being able to produce larger economies of scale.

Representatives from the gold extracting industry come to the conclusion that cyanide remains the most economically viable method for gold extraction, for a number of reasons including the costs of the materials of construction which are used to build the plant. They highlight the fact that many alternative reagents are just as toxic for the environment as cyanide. Alternative techniques do exist but they are not known to have large scale applications in Europe.

For NGOs, the argument of economic viability is not an option, since cyanide is seen as a threat, both for the environment and the populations living near the gold extraction plant. A number of NGOs are actively campaigning against the use of cyanide for gold extraction in the EU, such as the "Coalition for a Cyanide Free Romania", a civil society initiative that was formed to support a legislative proposal to ban cyanide in mining in Romania. Its concerns are based on social, economic and environmental grounds⁵⁹.

⁵⁹The "Coalition for a Cyanide Free Romania" consists of several environmental NGOs such as Greenpeace CEE, the Independent Centre for the Development of Environmental Resources, the Partnership Foundation, Terra Millennium III, Otus, Focus Eco Center, Sun Valley, Green Transylvania etc. This coalition supports the legislative proposal submitted to Romania's parliament by Senators Peter Eckstein Kovacs (The Democratic Union of the Hungarians in Romania) and Gheorghe Funar (The Great Romania Party). Accessible at: www.bancyanide.ro/, retrieved 12 March 2010

4.3. RECOMMENDATIONS

The use of cyanide for gold extraction can be accepted if the safety standards of the Directive are fully applied throughout the EU, so that tailings are never in direct contact with the environment. The most obvious recommendation would therefore be to ensure a proper implementation of the the safety standards of the Mining Waste Directive¹¹ and that these are applied in all EU countries, through appropriate enforcement, inspection and control of the existing provisions. 25 Member States have transposed the Directive, of which 22 have done this fully. Whether the Directive wil be applied in the same way throughout Member States remains open to question.

In order to meet the limit values of the Mining Waste Directive, a cyanide destruction process must be ensured in every gold extraction plant, and this should be ensured when permits are given and facilities inspected. No production of gold should be authorised within the EU without a destruction step. The destruction equipments already exist in all European plants working today, and the recommendations could therefore be adapted accordingly. The recommendations of the International Cyanide Management Code (ICMI)¹⁵ could be used to reinforce cyanide management legislation, although it is considered that the recommendations of the ICMI are de facto implemented through existing EU legislation (see section 1. 3. 3).

Further best practices to consider would include:

- Voluntary industry monitoring of all cyanide-related compounds at mines, with public release of the information
- Adoption of stricter environmental standards for all mining operations.
- Greater public disclosure of the environmental standards of all mining operations
- Appointment of citizen oversight boards at all mines that use cyanide to ensure public access to information.
- Independent environmental audits of all mining operations that use cyanide.

A further step would be the banning of cyanide. In this case, the choice of the most appropriate alternative to cyanide for gold extraction would depend on the types of ores present in the EU and on the choice that one would wish to make, emphasising either the economic viability of the product or the reduction of environmental impacts, and on the availability and applicability of the new techniques.

Finally, gold recycling is seen as the main alternative to gold extraction itself, since a large part of gold found in electronic waste is thrown away and landfilled every year.

Experts contacted:

- Johannes Drielsma, Euromines
- Gavin Mudd, Monash University, Australia
- Ruth Rosenhek, Director of the Rainforest Information Centre, Australia
- Steve Burks, Director at Bateman Engineering
- Cyrille Deshayes, WWF (no response)
- Olivier Jacquin, Heraeus (no response)
- Jeremy Swan, Cicero, for the World Gold Council (no response)
- Christian Schaible, European Environment Bureau (no response)
- Greenpeace (no response)